QUANTITATIVE ASSESSMENT OF THREE COMMONLY USED TREATMENT MODALITIES FOR NAVICULAR SYNDROME IN THE HORSE

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Nomenclature

NS – Navicular Syndrome

P2 – Middle or Second Phalanx

P3 – Third or Distal Pahlanx

DDFT – Deep Digital Flexor Tendon

NSAIDs – Non-steroidal Anti-inflammatory Derivatives

DIPJ – Distal Interphalaangeal or Coffin Joint

%BWF – Percent Body Weight of Force

LFL – Forelimb Generating the Lower Baseline %BWF

CFL – Forelimb Generating the Higher Baseline %BWF

TA - Triamcinolone Acetonide

INTRODUCTION

Navicular syndrome (NS) is a poorly understood, incurable degenerative condition of the distal sesamoid bone and/or its supporting soft tissue structures.[1-4] It is a common source of pain resulting in lameness that hinders the performance of many horses regardless of discipline.[5] Diagnosis of NS is based on many factors but is not always straightforward. Most often, a subjective lameness assessment is utilized not only for determining baseline lameness, but also for response to the treatment modality employed to manage the condition. Subjective lameness assessment is not always standardized and is dependent on the opinion and experience of the examiner. With the development of quantitative gait analysis technologies such as the force plate, equine lameness can now be evaluated in an objective fashion.[6-10]

The first two chapters review the anatomy of the equine navicular apparatus and provide a literature review describing the etiology, clinical presentation, diagnosis, and treatments used to manage NS in the horse. Reports utilizing force plate technology in the diagnoses of equine lameness are also presented.

The remainder of the text describes a clinical investigation aimed at objectively and quantitatively evaluating lameness following initiation of combinations of three commonly used treatment modalities for NS using force plate technology. The treatment modalities evaluated were heel elevation shoeing alone, heel elevation shoeing in conjunction with phenylbutazone, heel elevation shoeing in conjunction with distal interphalangeal joint (DIPJ) corticosteroid injection and all three in combination. Our hypothesis was that the described method of heel elevation shoeing would increase mean % body weight of force (%BWF) applied to the forelimbs of horses suffering from NS. We also suspected that the addition of phenylbutazone and/or DIPJ corticosteroid injection to this shoeing technique would demonstrate a further increase in forelimb mean %BWF.

CHAPTER I.

ANATOMY

The distal sesamoid bone or navicular bone of the equine is a small boat shaped bone located in the palmar/plantar distal aspect of the foot. It is anatomically positioned in such a way that its dorsal surface articulates with the distal end of the middle phalanx (P2) while the distal most extent is connected to the distal phalanx (P3) by the impar ligament. The palmar/planter (flexor) surface of the navicular bone is bordered by the tendon of the deep digital flexor muscle group (DDFT) as it courses to its insertion on P3. Between the navicular bone and the DDFT lies the navicular bursa. This is a fluid filled synovial structure which provides a gliding surface for the DDFT across the navicular bone when the horse is in motion. The suspensory or collateral ligaments of the navicular bone originate from the distal aspect of the first phalanx and insert on their respective medial or lateral border of the navicular bone. These soft tissue structures along with the navicular bone comprise the navicular apparatus. Disease of any one component of the navicular apparatus can result in lameness leading to the diagnosis of NS.

CHAPTER II.

LITERATURE REVIEW

Navicular syndrome

Definition

Navicular syndrome, also termed navicular disease, naviculitis, or podotrochleosis, was first reported in 1752.[11] This condition can be defined as a chronic forelimb lameness attributed to pain originating from one, some or all of the structures comprising the navicular apparatus. Although it is a progressive, degenerative condition for which there is no cure, many treatment modalities have been advocated attempting to manage this painful condition. [11-20] Thus, many horses affected by this disease process can be functionally sound and able to perform in equine activities.

Etiology

Many attempts to define the exact pathogenesis of navicular syndrome have been made, however, efforts to experimentally reproduce the disease have not been successful.[3] Therefore, all proposed etiologies remain speculative. Although the cause remains unclear, two main theories of pathogenesis have evolved. One is the theory of vascular compromise to and/or from the navicular region. This theory

Suggests that a lack of blood flow to the navicular region results in pain and ischemic damage to the navicular bone. The resorption of necrotic bone tissue leads to cystic lesions and subchondral sclerosis of the navicular bone. Alternatively, occluding venous return from the heel area of the foot results in venous congestion, increased bone marrow pressure and pain within the navicular bone. However, attempts to induce NS with various forms of vascular compromise have been unsuccessful and pathologic changes consistent with thrombosis and/or ischemia have not been observed.[21-25]

The second theory of pathogenesis for NS involves abnormal biomechanical function or biomechanical trauma.[12,23] During motion, the DDFT compresses the navicular bone dorsally against P2 and P3. The amount of force exerted by this tendon is dependent on many factors including conformation, shoeing, body weight, and the speed at which the animal is traveling.[26] In most horses, the force exerted is within an acceptable range however, in horses with predisposing abnormalities, the force exerted can become excessive resulting in damage to the navicular apparatus.[1] Thus, poor conformation, improper trimming/shoeing, intense training or use, excessive body weight and genetics have all been implicated as predisposing factors to the development of NS.[1,2,5,27]

Clinical Significance

NS is one of the most common causes of forelimb lameness in performance horses. It is responsible for an estimated one-third of all chronic forelimb lameness in horses.[1]

Clinical Presentation

The classic presentation of horses suffering from NS is a middle aged (8-14 years) performance horse with a chronic bilateral forelimb lameness.[1,3,5,11] The owner many times will complain of a problem originating in the shoulder.[1] Lameness can range from mild to severe depending on the stage of disease. Lameness may worsen after exercise or trimming/shoeing and the horse may be observed pointing one foot consistently or alternating feet. Less commonly a horse will be presented with an acute onset of lameness.

Diagnosis

Prior to the mid 1980's, diagnosis of NS was routinely based on the clinical presentation classically consisting of bilateral forelimb lameness improved with palmar digital perineural or distal interphalangeal joint anesthesia.[12,28] However, many more lameness etiologies can be improved with these diagnostic techniques thus a more in depth examination is needed. Accurate clinical diagnosis of NS begins with a thorough history and physical examination. Abnormalities such as under-run heel, hoof asymmetry, increased digital pulse and distal interphalangeal joint effusion although not pathognomonic, are common observations in horses suffering from NS.[1,3,5,27] Hoof testers should be applied to the soles of both forelimbs. Pain is often but not always observed across the heel area.[1,3,5,11,27]

Following physical examination, a comprehensive lameness evaluation should be performed. Observation of the horse's gait at a trot on a firm surface is important. In some cases it may be difficult to observe lameness in the straightaway but turning the horse in tight circles exacerbates the lameness.[1,3,11,12,27] A number of distal limb flexion and extension tests have been employed to aid in the clinical diagnosis of NS although none are specific to the disease. [1,3,5,11,12,27]

Improvement in lameness by desensitization of the caudal heel area with palmar digital perineural anesthesia is seen in 90% of horses with NS.[1,3,5,11] Intra-articular anesthesia of the distal interphalangeal joint can also alleviate pain originating from the navicular apparatus,[29] however neither of these techniques is specific. Perhaps the most specific analgesic technique for NS is local anesthesia of the navicular bursa.[3,12,27] Although more specific, this technique is technically more challenging for the veterinarian and often omitted.

Once the clinical diagnosis of NS is highly suspected, imaging of the area to confirm pathologic change is performed. Many imaging modalities have been utilized in the diagnosis of NS. By far the most common and most readily available to the majority of equine practitioners is conventional radiography. Others include ultrasonography, nuclear scintrigraphy, computed tomography and magnetic resonance imaging.

Conventional radiography usually consists of lateromedial, dorsoproximal-palmarodistal oblique and palmaroproximal-palmarodistal oblique projections. These three views allow visualization of the navicular bone in three different plains, however, the soft tissue structures cannot be evaluated. Therefore, radiographic imaging findings may not correlate with clinical findings.[30,31] Nuclear scintigraphy can also be misleading due to false positive and false negative results.[32] Ultrasonography of the equine foot is limited by the poor acoustic window afforded by the palmar aspect of the foot.[30] Computed tomography provides high-detail tomographic images many times identifying osseous lesions not seen by conventional radiography and magnetic resonance imaging provides superior contrast for recognizing soft tissue lesions.[30] However, closed computed tomography and magnetic resonance imaging scanners necessitate general anesthesia increasing risk to the patient and cost for the client.[30]

Treatment Modalities

Most equine practitioners agree that some type of corrective/therapeutic shoeing is the basis for treatment for NS and other treatment modalities should be used in conjunction.[1] Correction of any pre-existing hoof abnormalities i.e. hoof imbalance, is the first goal.[14] Several shoeing techniques have been employed attempting to improve lameness of horses with NS. The most common involves raising the hoof angle by elevating the heel.[12,14] Full bar and egg-bar shoes have also been advocated to provide extra support for the palmar aspect of the foot.[1,12] A rolled toe in conjunction with these shoe types serves to ease breakover.[1] Improvement has also been achieved with the natural balance shoe.[4] Unfortunately, one shoeing method has not been shown to be superior in all cases.

Non-steroidal anti-inflammatory derivatives (NSAIDs), especially phenylbutazone, are the most common medications used to manage NS.[1,27,33] NSAIDs may only be necessary to break the pain cycle while the horse adapts to corrective shoeing. However, some horses may require additional medication intermittently associated with performance/athletic events and severely lame horses may need continuous therapy to maintain normal daily function. Traditionally, phenylbutazone has been thought to provide better musculoskeletal analgesia while flunixin meglumine has been considered better for visceral pain such as colic. However, a recent study reported similar analgesic effects of either medication for horses with NS.[34]

Intra-synovial injection of corticosteroids has been widely used to treat equine lameness. Corticosteroids have been shown to reduce volume and increase viscosity of synovial fluid and to stabilize chondroblasts.[35] However, long term corticosteroid therapy can have detrimental effects on articular cartilage and reduces hyaluronic acid synthesis.[35] Although the distal interphalangeal joint (DIPJ) and the navicular bursa have no direct communication,[36] administration of local anesthetic solution into the navicular bursa can alleviate lameness originating from the DIPJ 20 minuets following injection,[37] and substances injected into the DIPJ have been found in navicular bursa fluid and synovium and in the medullary cavity of the navicular bone.[29, 38] Therefore, injection of corticosteroids into either of these synovial structures has been advocated to manage NS.[18]

Palmar digital neurectomy has been advocated in an attempt to allow horses diagnosed with navicular syndrome to return to athletic soundness.[20] Numerous surgical neurectomy techniques have been described including guillotine transaction, perineural capping, carbon dioxide laser transection, and carbon dioxide laser coagulation each attempting to decrease the incidence of painful neuroma formation and increase time before reinervation.[12] One study has shown sharp guillotine transaction less likely to result in painful neuromas.[39]

Equine Lameness Analysis

Subjective

Traditionally, equine lameness assessment has been based on the subjective opinion of the examiner. Thus, differing opinions as to the severity of the lameness are often made depending on the experience of the examiner.[40] Uniform lameness grading standards are very important not only for record keeping, but allow different examiners to evaluate an animal for improvement. Several lameness grading scales have been developed in an attempt to standardize subjective lameness assessment.[41,42] The American Association of Equine Practitioners has provided a standardized 5-point scale[41] in an attempt to develop a universal standard, but even this scale is subject to the opinion of the examiner.

Objective

Force plates have been shown to be useful for kinematic and locomotor studies.[6-10] The force plate is able to record the maximal vertical ground reaction force generated by each limb as it strikes the plate with the horse in motion. Peak vertical ground reaction force has been found to be inversely correlated to the degree of lameness when normalized to body weight.[6,7] A recent study concluded that the mean percent body weight of force (%BWF) generated by the forelimbs of horses diagnosed with NS did not change day-to-day or week-to-week over a three week period.[15] Therefore, degree of quantitative lameness of horses with NS does not change over a short period of time.

CHAPTER III.

MATERIALS AND METHODS

Inclusion Criteria

Horses presented to the Oklahoma State University Boren Veterinary Medical Teaching Hospital for forelimb lameness evaluation and displaying clinical and radiographic evidence of NS were considered for this study. Clinical evidence of NS was defined as horses displaying bilateral forelimb heel area pain with hoof testers accompanied by bilateral forelimb lameness improved with palmar digital perineural anesthesia. Initial lameness was evaluated subjectively using the American Association of Equine Practitioners (AAEP) five point scale.[41] Standard navicular radiographic studies (lateromedial, 60° dorsoproximal-palmarodistal oblique, and 45° palmaroproximal-palmarodistal oblique) of both forelimbs were obtained and each navicular bone was scored by a board certified veterinary radiologist on a 0 to 4 scale.[31] Any horse receiving a combined score of 2 or more was considered to have radiographic evidence of NS. Animals with dispositions unsuitable for shoeing or force plate data collection were excluded. Participation in the research trial was requested from the owner of any animal meeting the above selection criteria. A signed client consent form was obtained and approval from the Oklahoma State University Institutional Animal Care and Use Committee was granted.

Animals

Twelve horses (eight geldings and four mares) with a mean age of 10 (STD 3.9) years were included in this study. The duration of lameness according to the owner ranged from one month to two years.

Quantative Assessment of Force

The peak vertical ground reaction force generated by the forelimbs was measured by trotting each horse across a floor-mounted piezo-electric force plate[a] at 2.50-2.90 m/s. This velocity was measured using a millisecond timer and two photoelectric switches[b] three meters apart. The peak vertical ground reaction force was measured initially in Newtons, converted to kg of force, and finally normalized to body weight by the Bioware software[c]. This value, %BWF, was then used for comparison between treatments. Six valid strikes to the force plate were averaged to obtain the mean %BWF generated by each forelimb at each data collection session.

Experimental Design

Data for each forelimb was collected at six different sessions. At the first session, the baseline mean %BWF was obtained prior to any treatment. At this data collection session, the forelimb generating the lower %BWF was denoted the lame forelimb (LFL) and the forelimb generating the higher %BWF was denoted the contralateral forelimb (CFL) for the duration of the study. All four hooves were then trimmed and balanced. Wide web aluminum three-degree wedge horseshoes[d] were applied to the fore feet and steel flat horseshoes[e] were applied to the hind feet with nails by an experienced farrier. Measurements reveal that these aluminum shoes are 57% lighter and have a 27% increase in surface area compared to a comparable flat steel shoe[c]. Special emphasis was placed on the heel area so that the bar of the shoe extended 3-4 mm abaxial to the hoof wall caudal to the last nail and 10-12 mm beyond the caudal most extent of the heel.

The second data collection session occurred 24 hours post-shoeing to evaluate the immediate response to heel elevation. An adaptation period of two weeks was chosen to evaluate the effects of heel elevation shoeing alone and therefore 14 days post-shoeing mean %BWF was recorded at the third data collection session. Subsequently, phenylbutazone (4.4 mg/kg [2 mg/lb], IV, q 12h) was administered for five treatments. This is considered the maximum short term dose of phenylbutazone.[44] Two hours following the last treatment, the mean %BWF was recorded at the fourth session measuring the combined effect of shoes and phenylbutazone. Immediately following the fourth data collection session, the DIPJ of the LFL was injected with 6mg of triamcinolone acetonide(TA)[f] The DIPJ injection was given a period of two weeks before evaluation and the mean %BWF was recorded at the fifth session measuring the combined effect of heel elevation shoeing and DIPJ TA injection. Although intra-articular injection of corticosteroids into the DIPJ is routinely performed bilaterally, only the DIPJ of the LFL was injected for this study. Since the horses were given a two week period before response to the DIPJ TA injection was evaluated, any significant change in %BWF could have been attributed to the additional shoeing adaptation time rather than response to the TA injection. Therefore, only one joint was injected in order to identify which treatment modality was responsible for any change in %BWF. Phenylbutazone(4.4mg/kg [2 mg/lb], IV, q 12h) was again administered for five treatments and two hours following the last injection mean %BWF was recorded at the sixth and final session measuring the effect of all three treatment modalities in combination. A recent study concluded that the %BWF generated by the forelimbs of horses diagnosed with NS did not change day-to-day or week-to-week over a three week period.[43] Therefore, the degree of quantitative lameness of horses with NS is not expected to change over the duration of the described experiment .

Data analysis

Since NS is a bilateral condition, data for each forelimb were collected and analyzed separately for improvement in the respective limb. Data collected 24 hours and 14 days post-heel elevation shoeing were compared to baseline data for significant change in mean %BWF. Statistical analysis was performed using a repeated measures analysis of variance techniques separately for each forelimb on a sample population and individual horse level with PC SAS Version 8.2.[g] Effects of each treatment were analyzed using ANOVA with the PROC MIXED method in SAS. Effects of treatment were analyzed using a LSMEANS statement. Effects were considered significant if $p \leq 0.05$.

CHAPTER IV.

RESULTS

Population results

Average baseline and treatment mean %BWF of the sample population is summarized in Fig. 1. Twenty-four hours following the application of heel elevation shoes, the average mean %BWF did not significantly change for either forelimb. However, following a 14 day adaptation period, heel elevation shoeing significantly increased average %BWF over baseline for both limbs. The addition of phenylbutazone to heel elevation shoeing significantly increased average mean %BWF of the LFL ($p < 0.0001$) and increased the mean %BWF of the CFL, however this was not statistically significant from fourteen days post-heel elevation shoeing alone ($p < 0.25$). When compared to data collected fourteen days post-shoeing, the addition of DIPJ TA injection of the LFL to heel elevation shoeing failed to show significant improvement in the average mean %BWF of either limb from shoeing alone ($p = 0.29$ for LFL and 0.88 for CFL). When compared to fourteen day post-shoeing data, all three treatment modalities in combination provided similar results to shoeing in combination with phenylbutazone with a significant increase of average mean %BWF of the LFL ($p < 0.0001$). The CFL again increased but was not statistically significant. ($p \leq 0.48$)

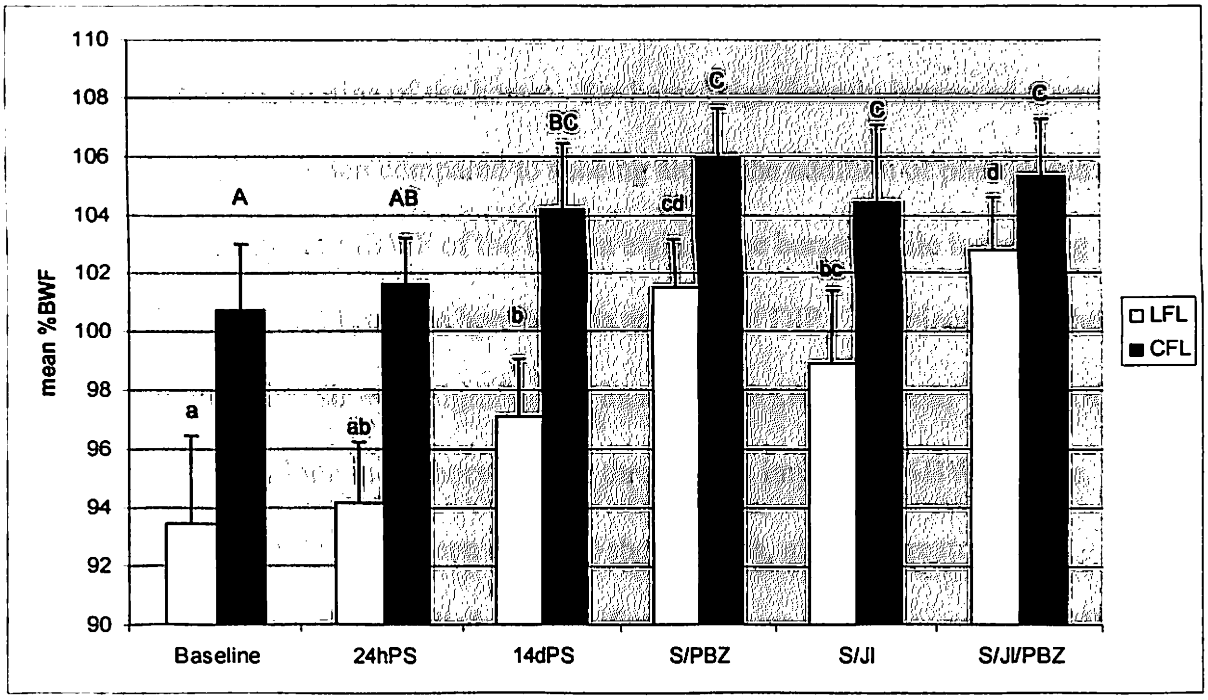

Fig. 1 Population Results - Average force expressed as mean percentage of body weight (%BWF) generated by the forelimbs of twelve horses with navicular syndrome prior to and following five treatment modalities. 24hPS = 24 hours post heel elevation shoeing; 14dPS = 14 days post heel elevation shoeing; S/PBZ = heel elevation shoeing in combination with phenylbutazone; S/JI = heel elevation shoeing in combination with distal interphalangeal joint corticosteroid injection; S/JI/PBZ = heel elevation shoeing in combination with both distal interphalangeal joint corticosteroid injection and phenylbutazone. LFL – Forelimb generating the lower baseline mean %BWF. CFL – Contralateral Forelimb. Values with the same letter designation (a-d & A-C) are not statistically significant from each other. n = 12.

Individual results

Twenty-four hours following the application of heel elevation shoes, significant improvement in the mean %BWF applied to the LFL of three horses and the CFL of three horses. For each limb, nine horses failed to show improvement or worsened 24 hours following application of the therapeutic shoes. However, following a 14 day adaptation period, heel elevation shoeing significantly increased mean %BWF over baseline of the LFL in nine of the horses. Six horses significantly increased average %BWF of the CFL. When compared to shoeing alone, the addition of phenylbutazone further increased mean %BWF of the LFL in eight of the horses while increasing the mean %BWF of the CFL in five horses. The addition of DIPJ TA injection of the LFL to heel elevation shoeing significantly increases the average mean %BWF of the LFL over shoeing alone in six horses while three horses improved %BWF of the CFL. When compared to fourteen day post-shoeing data, all three treatment modalities in combination resulted in a significant increase of average mean %BWF of the LFL of nine horses and an increase in mean %BWF of the CLF in two horses.

CHAPTER V.

CONCLUSIONS

The results of this study indicate that the described method of three degree heel elevation shoeing alone and in combination with systemic administration of phenylbutazone may quantitatively decrease lameness in horses suffering from NS. Although not statically significant, the addition of DIPJ injection of TA to three degree heel elevation shoeing may offer further quantitative improvement in lameness in individual horses. However, some horses may be refractory to these treatment methods and require other modalities such as alternate therapeutic shoeing techniques and/or NB injection to quantitatively decrease lameness.

CHAPTER VI.

DISCUSSION

Inappropriate or inadequate foot care is a common finding in horses with NS. Long toes, under-run heels and hoof imbalance can put excess strain on the navicular apparatus. Shoes that are too small and/or shoes that do not extend to or beyond the caudal most extent of the heel do not provide appropriate support.[12] The shoes used in this study were fitted in such a way to provide maximum support to the heel. The wide web provides additional surface area decreases force/unit area of ground contact and the reduced weight serves to decrease inertial kinetic forces on the distal limb. Although only three of the twelve horses improved 24 hours following the described method of therapeutic shoeing, the majority of the horses in this study significantly improved %BWF of their forelimbs indicating improvement in lameness following the 14 day adaptation period. This supports previous reports of an adaptation period necessary for corrective shoeing to relieve the inciting painful stimuli.

Results of this clinical trial indicate that horses suffering from NS may significantly increase the mean %BWF generated by their forelimbs fourteen days after being shod in the described fashion. These results support the biomechanical theory of pathogenesis, and heel elevation serves to decrease pain in the foot by reducing the pressure applied on the navicular bone. In this study, some of the horses did not change or significantly decreased mean %BWF with this shoeing technique.

This is consistent with other corrective shoeing methods, however a longer adaptation period may be necessary to fully recognize the benefit of this heel elevation shoeing technique.[1,13,14] Other corrective shoeing techniques for NS that do not utilize the heel-elevation principle, such as egg-bars, natural balance, etc., may have benefited these horses, however, horses shod with flat shoes have an increased maximal force exerted on the navicular bone by the DDFT compared to unshod horses.[45,46]

The addition of phenylbutazone to the described method of shoeing further improved the mean %BWF of eight horses. The musculoskeletal analgesic properties of NSAIDs are well documented. The dose of phenylbutazone used in this study (4.4 mg/kg [2mg/lb] q 12 h) was approximately 2g for a 500kg horse. This dose was chosen to provide maximum anti-inflammatory response in a short time period similar to the administration of phenylbutazone in association with athletic performance however, one report suggests a lower dose (4.4 mg/kg [2mg/lb] q 24h) may be as effective and reduces the potential for toxicity.[47]

Although the average quantitative lameness data obtained from the twelve horses in this study demonstrated no significant difference from shoeing alone, an increase in %BWF of the LFL was noted in six of the twelve horses 14 days following injection of TA. However the six other horses either demonstrated no change or a decrease the mean %BWF of the LFL following injection. One report advocates injection of corticosteroids in combination with hyaluronate directly into the NB of horses refractory to other treatments.[18] Hyaluronate in combination with corticosteroids has been shown to be more beneficial than corticosteroids alone[35] and may have further benefited the horses in this study.

Therapeutic shoeing in some fashion is considered the basis of treatment for NS by many practitioners. This experiment was conducted in such a way that all treatment modalities included and therefore was dependent therapeutic shoeing, however, changing the sequence of which the different treatment modalities were applied may have provided different results. For instance, phenylbutazone or DIPJ TA injection alone or the combination of these two treatments without the addition of therapeutic shoeing may have shown a quantitative change in %BWF of the horses. In addition, combinations of other therapeutic shoeing modalities and other medical and surgical treatments may alter the quantitative lameness of horses with NS.

Footnotes

a. Piezoelectric Biomechanics Force Plate System Type 9287920311, Kistler, Amherst, NY 14228

b. Infrared Photoelectric Sensor Model #49-551A, Radioshack Corporation, Fort Worth, TX 76102

c. Bioware Ver. 3.22 Type 2812A1-3, Kistler, Amherst, NY 14228

d. Elite Competition Shoe – 3-degree wedge, Victory Racing Plate Company, Baltimore, MD 21237

e. St. Croix Lite, St. Croix Forage, Forest Lake, MN 55025

f. Vetalog 6 mg/ml, Ft Dodge Animal Health, Ft Dodge, IA 50501

g. PC SAS Version 8.2, SAS Institute, Cary, NC 27513

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